



NASA STTR 2006 Phase I Solicitation

T6.01 Predictive Modeling Techniques for the Mechanical Behaviors of Powders, Granular Materials, and Soils

Lead Center: KSC

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Developing software models to predict the mechanical behavior of granular materials and powders is an area of on-going and active research and development. NASA has a need for advances in software modeling techniques to support a number of on-going initiatives. One such area is the prediction of stress/strain shearing and compaction response of powder insulation materials located inside the annular space of very large cryogenic dewars (e.g., 80 feet in diameter with a 3 - 4 foot radius in the annular space). This is an area of high interest to KSC due to the use of large cryogenic tanks at the launch pads and the problems associated with the insulation in them. Another area of interest is the mechanical behavior of lunar soil during drilling and digging, during construction and compaction (of berms), or during beneficiation and chemical processing of the soil (e.g., to remove water ice). This area is of interest to KSC due to the need for launch-site facilities to enable the assembly, flight qualification, and final checkout of spacecraft and payloads including the re-testing of last-minute modifications. Modeling the behavior of lunar soil in such facilities and comparing to the expected behavior in the lunar environment is a critical ability for developing launch-site facilities and procedures.

In both areas of interest, it is impossible to perform full-scale testing of the material in the relevant environment, and therefore extrapolation is necessary to compare small-scale or terrestrial experiments against what is expected in the full-scale or lunar environment. Extrapolation from one scale (or one environment) to another is very difficult and currently has a low probability of producing high-fidelity predictions. Unfortunately, without such extrapolation it is impossible to use an affordable small-scale (or terrestrial) test as a means to validate the design of hardware or to validate the expected behavior of the powder or soil in the full-scale (or lunar) case.

The best, presently-known method to do an extrapolation from one scale (or environment) to another is to produce a computer model to realistically simulate the physics of the granular material. The simulation can then be parameterized to make predictions in either scale or in either environment. The simulation can be benchmarked using the accessible scale (or environment), and then the parameterization can be adjusted to the inaccessible scale (or environment) to make the predictive extrapolation. Additional confidence in the extrapolation can be obtained by studying the model's sensitivity upon its various parameters within some experimentally-accessible range. Furthermore, the model can be used long-term as an engineering tool, iteratively refining it as new data become available from the full-scale application (or from the lunar environment). Thus, the model becomes a method to organize and compare new data as they become available across multiple scales and environments.

Innovations are sought in the area of multi-scale granular material modeling with true extrapolatory, predictive power across scales and environments. These innovations could be in the form of software techniques that integrate Discrete Element Models with Finite Element Models (or other software innovations), benchmarking techniques that integrate experimental methods with modeling methods in new ways, innovative analysis techniques, or any combination of the above. Other innovations will also be considered. The key point to the innovation is that it must extend the state-of-the-art in predicting granular/powder mechanical behavior. Innovations are particularly desired in the ability to model and predict powder shearing and compaction and to model lunar soil geotechnics.